DOCUMENT RESUME

ED 387 487 TM 023 235

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TITLE Variables Influencing the Indexation of the "Prior Knowledge State" Concept and a Conceptual Model for Research.
INSTITUTION Open Univ., Heerlen (Netherlands). Centre for Educational Technological Innovation.
REPORT NO ISBN-90-358-0589-5; OTIC-RR-2-2
PUB DATE 88
NOTE 23p.
AVAILABLE FROM Open University, Secretariaat OTIC/COP, Postbus 2960, 6401 DL Heerlen, The Netherlands.
PUB TYPE Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Artificial Intelligence; Background; Case Studies; Cognitive Psychology; *Cognitive Structures; *Concept Formation; Educational Psychology; Educational Research; *Experience; Foreign Countries; *Knowledge Level; *Prior Learning
IDENTIFIERS Operational Concepts

ABSTRACT

In educational psychology research the concept "prior knowledge" is not always clearly described, but it is important to distinguish prior knowledge state (PKS) components as well as possible and to elucidate the relations among these elements. An in-case-study was conducted into the operationalizing of the concept of prior knowledge and the PKS, investigating how PKS should be operationalized using a number of variables. Data collected in a literature search and an enquiry among specialists is interpreted. Seventeen experts in cognitive psychology and artificial intelligence responded to a questionnaire on PKS. Their responses were used to derive a provisional conceptual model with eight variables: (1) the nature and amount of information and skills; (2) availability of cognitive structure; (3) structuring of the cognitive structure; (4) relevance of information in respect to the learning objectives; (5) the pace or duration of the learning process; (6) durability of what is retained; (7) previous education; and (8) work experience and age. Seven figures illustrate the discussion. (Contains 13 references.) (SLD)

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Variables influencing the indexation of the 'Prior Knowledge State' concept and a conceptual model for research

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VARIABLES INFLUENCING THE INDEXATION OF THE 'PRIOR KNOWLEDGE STATE' CONCEPT AND A CONCEPTUAL MODEL FOR RESEARCH

OTIC Research Report 2.2

F.J.R.C. Dochy

CIP- gegevens koninklijke bibliotheek, Den Haag

Dochy, F.J.R.C.

Variables influencing the indexation of
the 'Prior Knowledge State' concept
and a conceptual model for research /
F.J.R.C. Dochy. - Heerlen: Open University,
Educational Technology Innovation Centre (OTIC)
- Ill. - (O.T.I.C. research report 2.2)
Met lit. opg., reg.
ISBN 90-358-0589-5 geb.
SISO 450.43 UDC 371.012
Trefw.: prior knowledge in the learning process; research

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Summary.

In research in educational psychology the concept of "prior knowledge" is not always clearly described. It is not easy to describe. Scholars tend to have different ideas about the interpretation of the concept. The "prior knowledge state" (research report 1) comprises various elements. Furthermore, these elements are not always clearly distinguished. It is however important for research into the role of prior knowledge to distinguish the different PKS components as well as possible, and to elucidate the relations among these elements. The research before us offers an indexation of the PKS concept as a basis for a conceptual research model.

Within the context of the research project on "the role of the prior knowledge state in the learning process among adult students in a modular education system", an in-case-study was carried out into the operationalizing of the concept of "prior knowledge", hereinafter "prior knowledge state".
The object of this study was to investigate how PKS could be operationalized using a number of variables. Further, we looked into the question of the method to be used for measuring PKS and there is a report on this in a subsequent research report.
In this report the data collected in a study of the literature and from an enquiry among specialists is reproduced and interpreted.
Finally on the basis of the results, a conceptual model for the research of the PKS is proposed.

1. Valid indexation.

In this section we will explain the terms "validity", "indexation" and "operationalizing" that are used extensively below.
The pivotal questions in this case study are : which variables indicate the existence of prior knowledge on the part of students? Which variables represent the "prior knowledge state" in a valid way?
Segers (1977) writes that the concept of validity relates to the question of whether the theoretical characteristic at issue can be ascertained by means of the phenomena selected. The validity principle means that research data must be such that it is legitimate to move from the level of empirical variables to that of theoretical concepts.
Carminus and Zeller (1979, p.12) formulate this simply by saying that "an indicator of some abstract concept is valid to the extent that it measures what it purports to measure." De Groot uses the terms "concept-as-meant" and "concept-as determined". The requirement that the variable represent the concept-as-meant as adequately as possible is a special requirement in respect of the relationship between concept and (operationally defined) variable. "The issue is whether the variable is valid in being representative, or whether the "validity" is that of a variable. A variable is valid if it is representative of a theoretical, more abstract concept; this means that a theoretical characteristic can be measured in terms of empirically chosen phenomena.

2. Indexation and operationalizing.

There is no clear consensus about the meaning of the terms indexation and operationalizing. Swanborn (1984) defined operationalizing as "the translation" of more or less general characteristics into observable phenomena which seem to represent the characterics in question as well as possible in the social system or phenomenon investigated at that particular place and time." The result is an operational variable, an instrument of measurement. The term "instrument of measurement" does not mean that numerical values have already been allocated to empirical phenomena following particular rules. The term "instrument of measurement", for operational variables has to be taken broadly here. A general characteristic is that of a construct in terms of which a collection of units falls into a hypothetical set. Operationalizing means looking at a variable which splits the set in such a way that the division that arises accords as

well as possible with the intended hypothetical split in the set. The researcher chooses a variable in which, in his view, the general characteristic in this place and at this time are best represented. Most constructs are an initial phase on the way to operationalizing, divided into separate and distinguishable facets or aspects. De Groot (1961) in speaking of a "more or less general characteristic" speaks of a concept as meant. An appropriate operational variable might be called a concept-as-determined. Boesjes-Hommes (1974) makes, like Swanborn, no distinction between operationalizing and indexation. He employs them as synonyms. The operationalizing of theoretical concepts is an empirical event, which can be referred to as "indexation". Indexation is the "transfer of theoretical concepts from the theory into variables, formulated in the language of research." Theoretical concepts are used as functional entities, as static clusters of characteristics, that only begin to function in a theory. This is illustrated schematically in figure 1. The indexation here takes place progressively moving from dimensions to indicators; from indicators to items.

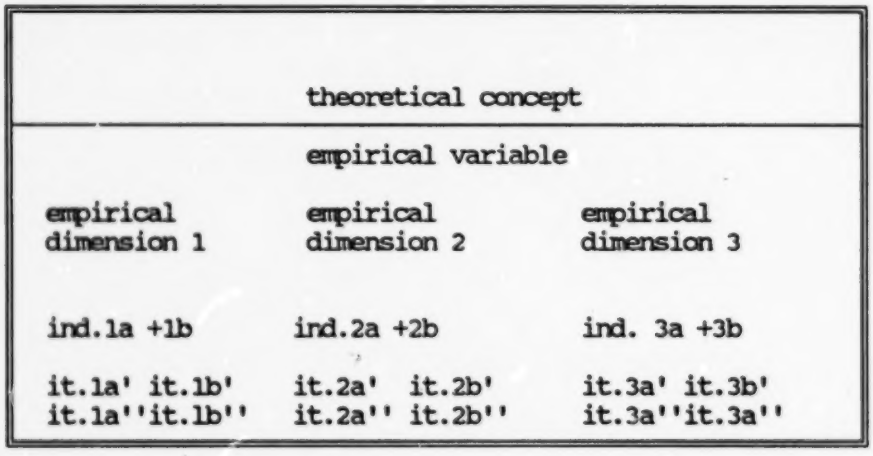


Figure 1: developed operationalizing of the empirical variable (Boesjes-Hommes, 1974).

Indexation or operationalizing is valid when "the meaning of the empirical variable-as-determined in semantic, structural and functional terms accords with the meaning of the theoretical concept as meant." (Boesjes-Hommes, 1974, p.142). Theoretical and empirical language should in other words be equivalent in three respects : the semantic, structural and functional. Equivalence in semantic terms means that the inherent significance that we allocate to theoretical concepts must be adequately present in the operationalizing.

Structural equivalence means that the relationship among the various characteristics remains the first specification of a theoretical concept in operationalizing. The functional equivalence, in particular the functional validity of the concept after operationalizing is determined by the objective of the research. Furthermore, the translation from a theoretical language into a particular empirical language also determines the research objective that in its turn is dependent on the theoretical context. These three aspects of equivalence are not separate from one another because of the semantic and structure dependent character of functional meaning. The research objective determines what semantic and structural significance we should apply.
In contradistinction to Boesjes-Hommes and Swanborn, Segers (1977) introduces the distinction between indexation and operationalizing within the process of translation from the theoretical to the empirical. The significance of these terms and their interdependence is made clear in figure 2.

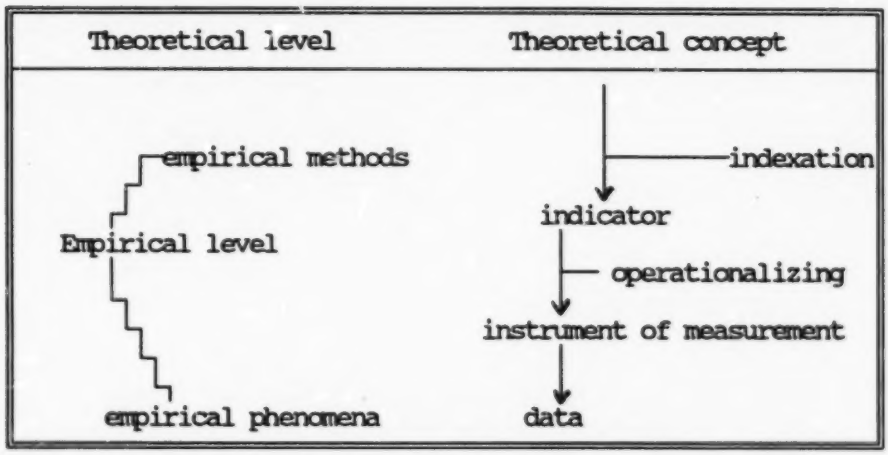
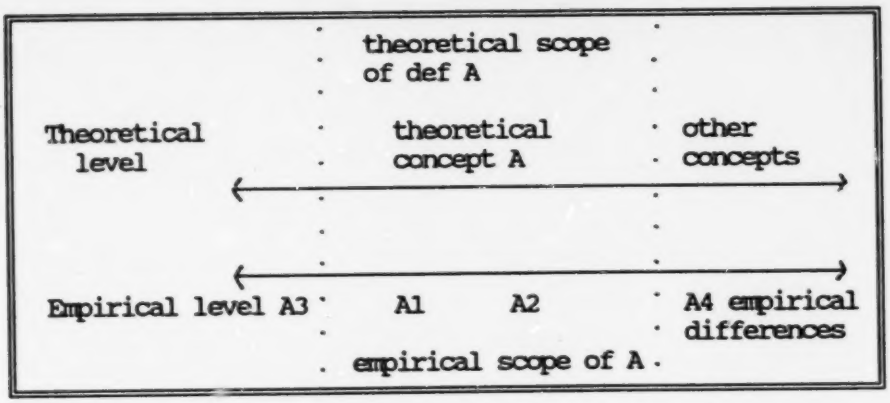


Figure 2: Indexation and operationalizing (Segers, 1977).

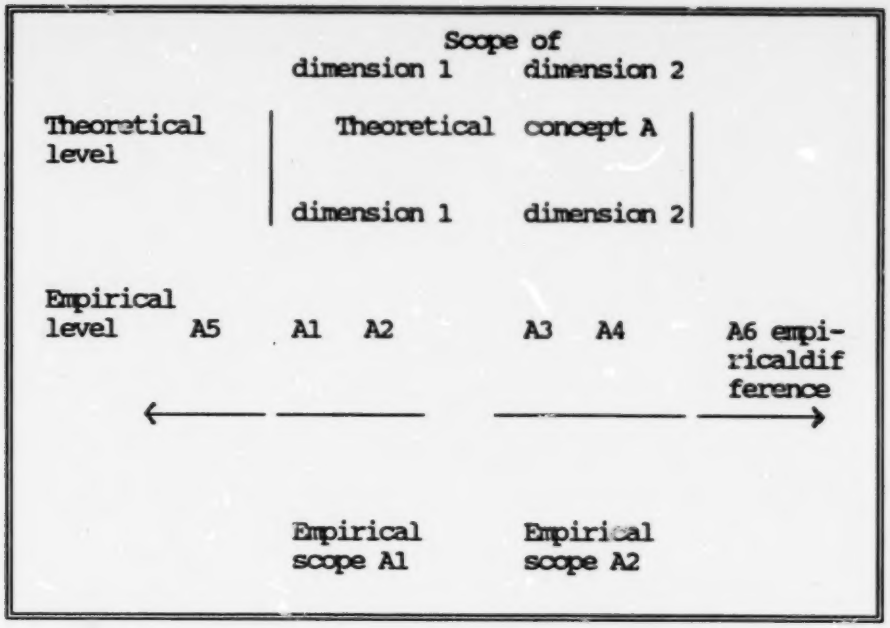
In this study, we shall use this clear distinction, as it has been introduced by Segers.
Operationalizing takes place in this schema at a different level from the one at which Swanborn places the concept. Segers regards indexation as the first step in the "translation" of the abstract concept and operationalizing as a second step, in particular, the translation of the empirical phenomena into an instrument for measurement in the narrow sense (for example questions, a thermometer, a test...).
Indexation is according to Segers also valid when the chosen indicators accord in their meaning with the theoretical concept (Figure 3).



A1 and A2 : valid indicators
A3 and A4 : invalid indicators

Figure 3 : valid and invalid indicators (Segers, 1977).

The set of empirical phenomena which corresponds to the theoretical definition A in principle comprises valid indicators.
However, a concept can often distinguish more than one dimension. Indexation is only valid when all aspects are represented in the indicators, which are distinguished in the definition of the concept as a dimension. The operationalizing of a two-dimensional concept was mapped out by Segers (Figure 4).



A1 A2: valid indicators for dimension 1, invalid for 2
A3 A4: invalid indicators for dimension 1, valid for 2.
A5 A6: invalid indicators for both dimensions.

Figure 4: Operationalizing of a two-dimensional concept (Segers, 1977).

Within the context of the significance that we assign to the concepts indexation and operationalizing, valid operationalizing relates to the validity of the instrument of measurement. There must be no other harmonics in the "melody" and there must be no background noise. In one question for example, only information on the intended indicator can be recalled and no simultaneous particular expectation as to the desirable answer.

3. Indexation of the "prior knowledge state" concept.

When applied to this project, it means that we turn our attention to the indexation of the concept. The different indicators or dimensions - both are largely used as synonyms - and the variables are examined in this. In one and the same situation, various aspects of a concept-as-meant are

often active at the same time. For that reason most constructs are reduced to their various components as the first step in indexation. The distinguishing of variables is also a first step on the way to operationalizing. The characteristic-as-meant, i.e. the prior knowledge state, is divided into separate aspects which can be distinguished from one another. These aspects are ranged along dimensions. Each of these dimensions is further operationalized in variables.
The questions to be put in this research are : what variables represent the concept-as-meant, i.e. the prior knowledge state, in its various dimensions? What variables are seen as representative of the dimensions distinguished or what variables adequately cover the indicators to be measured? Questions are raised about the semantic equivalence between the indicators (or dimensions) and the theoretical concept on the one hand and between the variables and indicators on the other.
The operationalizing of the prior knowledge state can be represented schematically (figure 5).

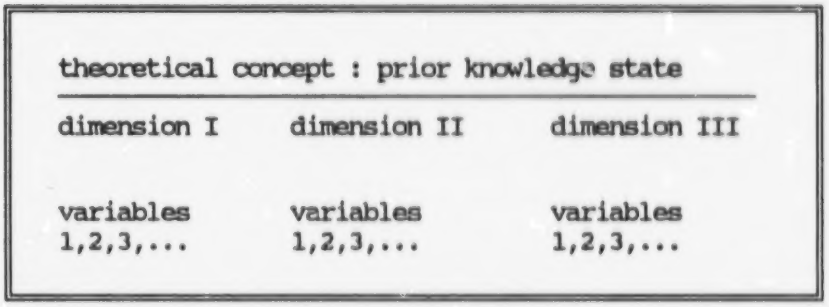


Figure 5. The operationalizing of the theoretical concept prior knowledge state.

4. Methods of validation.

Generally speaking, the following methods are distinguished : validation of content, validation of criteria and validation of concepts. N.B. the relationship between the instrument of measurement and the criteria is pivotal in the validation of the criteria; in construct validity the theoretical construct is pivotal .
In this case it is clearly a question of content validity.
Other terms for content validity are : logical validity, face validity and sense-validity. Segers (1977) claims that "the relationship between the construct-as-meant (theoretical characteristic) and construct-as-measured (empirical

variable) is supported by arguments which indicates that the "content" of the indicator accords with the "content" of the theoretical characteristic. Face-validity is the assessment of indicators on their "external appearance" as a representative of a theoretical concept or dimension.

The consensus that can arise within a scientific forum about the validity of an indexation raises face-validity, from a methodological point of view, above pure subjectivity. The judgment of experts (fellow-researchers, content experts) determine content validity. Content validity can however only be approached when the researcher pays attention in the first instance to the quality of instrumental design. Segers (1977) distinguishes four essential stages in the design of a content valid instrument :

a) theoretical concern with the elucidation of the significance of the content of the construct involved;
b) the recognition and specification of the theoretical dimensions of the construct;
c) the careful choice of indicators for each of the dimensions distinguished;
d) the assessment of the manner in which the different indicators have to be joined to one valued determinant.

Boesjes-Hommes (1974) agrees with Segers that content validity can be approached by calling upon assessors. He speaks in this connection of substantive testing used to investigate the equivalent in the semantic meaning of a construct and its operational derivatives.

In this project we shall investigate whether the content of the dimensions accords with the theoretical construct of the "prior knowledge state". This method of content validation which accords with the various stages distinguished by Segers (1977) includes a theoretical discussion in the research and also a theoretical consideration and elucidation of the theoretical construct. This is by means of a study of the literature and an in-case study on PKS within a scholarly forum, i.e. among various experts in the area of cognitive psychology and artificial intelligence.
This inter-subjective assessment by experts will in the first instance be directed at the validation of the significance of the semantic and structural equivalence. The functional equivalence will be discussed in the research group and tested by the results of the exploratory research among O.U. students.

5. Indexation by means of research into the literature and the judgment of experts.

5.1. Research into the literature and research into the perception of experts with reference to PKS.

In the first instance research into the literature refers to the use of prior knowledge (PKS) by students in higher education, research in the area and theories on the facilitating influence of prior knowledge. This study is reported on in research report 1: "The effect of the prior knowledge state on learning: theories and research".
A second piece of research on the literature is directed at the operationalizing of the concept of "Prior Knowledge State". In this contribution, we shall examine the results again.

A questionnaire was constructed comprising general questions on the significance of the PKS construct and the methods of establishing it. Potential respondents in this investigation were all experts in the area of Cognitive Psychology or Artificial Intelligence. In order to make a selection from this group of experts who were active in research on prior knowledge, an inventory was made of the Dutch speaking experts during the study of the literature. A mini questionnaire was sent to 27 experts.
Replies were received from 17; 7 respondents did not wish to be regarded as experts, because they were not directly involved with the topic; 10 respondents answered all the questions. In the appendix there is a brief summary of the results.

5.2. Indexation of the "prior knowledge state" concept.

A great deal is made of the distinction between nominal and real definitions in the indexation and representation of concepts in definitions. In nominal definitions, the user introduces the meaning of the term by stipulation. Anyone who does not know the construct is directed towards the meaning within which the construct is used. Nominal definitions of the "prior knowledge" construct are much in evidence in the literature. They are largely described as "the totality of knowledge and skills of the subject" or "what he knows already beforehand". Real definitions are few and far between. Perhaps this conclusion can be related to another conclusion from this study, that is that prior knowledge thus far has been virtually exclusively measured by means of tests of knowledge.
In a real definition, the manner in which the definition of a construct replicates reality is pivotal. The characteristics that the object does or does not meet are given here. The

meaning ascribed to the construct "prior knowledge" (research report 1, chapter 3) indicates that two dimensions can be distinguished : information and skills.
Real definitions come more often from the experts than the literature. Relevant descriptions are given here. The descriptions that proceed from know-how already acquired, i.e. prior knowledge that has a clear influence on performance (see research report 1, page 1) provides little that helps to make the construct of prior knowledge usable and they are not included here. For example, the statement that prior knowledge is that part of a person's knowledge that influences the learning, processing, reproducing and using new material in a given situation. Such definitions do not say what prior knowledge is, but what has been established by means of research.
A second example is the following quote : "In the natural sciences and mathematics it can be stated that the ability to solve a type of problem gives an indication that the student possesses the prior knowledge necessary to learn a particular part of the subject. In this "reversed" situation the performance is supplied by solving problems or carrying out work which is unjustly regarded as the proof of the influence of prior knowledge.

5.2.1. The Prior Knowledge State described by experts.

The Prior Knowledge State described by experts as:

- the degree to which the student already possesses knowledge/insight/skills. It is not just a question of the presence of particular element or skills, but also the structure of knowledge, the degree to which knowledge, insight and skills are associated with stimuli so that the student is able to activate and use them at the right moment.
- the information present in his or her memory which is in principal accessible and can be recalled. Access and the ability to recall something does not imply that the student must be able to (re)produce the prior knowledge by himself and from within himself. Knowledge which can be (re)produced with the help of hints, cues, tasks is to be seen as prior knowledge.
- in general it is organized within a cognitive structure that makes it more or less easy to apply in the process of understanding dependent on the nature of the structure. In addition to organization, the ease with which prior knowledge is activated within the text to be studied or the learning context is an important determinant of the learning process.
- the knowledge that a learner has in the area in which he is to be further trained or taught. Prior knowledge can be practical knowledge and theoretical knowledge.

- all the knowledge that is already stored in the memory before the "criterion task" was initiated and that becomes active in the carrying out of the task (for example learning new material) .
- all existing knowledge of the subject. (Facts, definitions, laws, procedures, situations, etc.) necessary for absorbing and processing the new knowledge, and which is there to fall back on in education (textbooks). It is not only the content that is important, but also the availability of the prior knowledge; this is to an important degree determined by the structure of the knowledge.
- possessing one or more schemas in which newly acquired knowledge can be applied.

From the descriptions it appears that the experts highlight a number of PKS characteristics. Emphasis is on five aspects : the presence of knowledge, insight and skills, its structured nature, its dynamic nature (ongoing updating), the availability of information required; knowledge and skills, present before the implementation of learning activity.

5.2.2. The concept of prior knowledge in the literature.

In the various theories and research on prior knowledge (research report 1) as we said before, one finds virtually exclusively normative descriptions. It is interesting that a distinction is made between various sorts of prior knowledge. There is often reference made to declarative and procedural knowledge, semantic and episodic knowledge, and strategic knowledge.
Using concepts like episodic and semantic knowledge is difficult. In practice the distinction cannot be made too clear. Episodic knowledge reflects the totality of personal experience in its spatio-temporal context, comparable to a historical document. Episodic knowledge is contextual and accidental. Semantic knowledge comprises a representation of the external world, abstracted from the context and is permanent and necessary. This knowledge is largely expressed in models of memory as a system of related concepts. Each model that makes a distinction must also be provided with an interface between episodic and semantic knowledge.
This knowledge is largely expressed in models of memory as a system of related concepts. Each model that makes a distinction must be equipped with an interface between the episodic and semantic knowledge. How often do we have to see a leopard to know that its spots are a defining characteristic? For this reason we shall, in the present study, restrict ourselves to the use of a somewhat better defined concept of declarative knowledge and procedural knowledge. Declarative knowledge is knowledge of facts, the significance of symbols, concepts and principles in a

particular field. Procedural knowledge is largely knowledge of actions, manipulations and activities.
The essential difference between them is that procedural knowledge relates directly to an action or activity, whereas declarative knowledge requires interpretation for it to lead to action (Messick, 1984). Anderson(1980) calls the distinction declarative - procedural; "knowing that" and "knowing how" respectively. Strategic knowledge is related to procedural knowledge. A strategy can be seen as a general plan of action in which a sequence of separate cognitive actions is set forth (Posner and McLeod, 1982).
The conceptualization of this sort of knowledge is fairly vague. Cohen (1983) makes no distinction between it and procedural knowledge. Both comprise skills and plans of activity. According to De Jong (1986) the difference is in the degree of specificity. Procedures are related to a small part of the solution procedure. They are largely domain specific and comprise algorithms and heuristic procedures. Strategies relate to total solution procedures and are often used where there is more subject content (Schoenfeld, 1983; De Jong, 1986). There is however never any question of there being a clear dichotomy but more of a sliding transition, a cline. The terms procedural and strategic are often used interchangeably.
Finally, it has been thought necessary to look at the importance attached to experience as a source of PKS. More research has been directed at the role of experience preceding a learning activity primarily under the influence of the "experimental learning school" in the US. In a forthcoming research report this school will be thoroughly analyzed.

In summary, this means that research is directed at declarative knowledge - called "information" here - and procedural and strategic knowledge - called skills.
Further, in the literature, attention is largely directed at the structure of prior knowledge. Various theories are formulated (research report 1) on the availability of information, its restructuring , etc.

In this study PKS will always be looked upon as domain specific prior knowledge (research report 1).
The Prior Knowledge State can be described as the knowledge state comprising prior information (knowledge and insight; declarative knowledge) and skills (procedural and strategic knowledge) which meet the following conditions :

- they are present before the implementation of a particular learning task
- available or able to be recalled
- relevant for the achievement of the objectives of the learning task
- organized in structured schemas
- to a degree transferable, applicable or transferable to other learning tasks, within and possibly outside the domain
- dynamic in nature.

The Prior Knowledge State can be schematically presented as a knowledge state that comprises a particular moment)before the implementation of a learning activity) that is available for the achievement of particular learning objectives (fig.6).

Domain specific Prior Knowledge State

information	skills
(knowledge,insight)	(analyzing, deducing,etc.)
declarative knowledge	procedural knowledge strategic knowledge
experiential knowledge	experiential skills

Figure 6. The Prior Knowledge State as established at a particular moment for the implementation of a learning activity.

5.3. Variables that indicate Prior Knowledge State.

In the literature and among experts there is general consensus on a number of aspects which reveal PKS. These are part of the proposed conceptualization.
Further a limited number of variables which give a valid indication of prior knowledge : pace of study, durability of what is learned, education and work experience.

6. Provisional conceptual model for research of the Prior Knowledge State.

From the above, eight variables can, in principle, be derived for a conceptual model for research into PKS :

1. the nature and amount of information and skills
2. the availability of cognitive structure
3. structuring of the cognitive structure
4. the relevance of information in respect of the learning objectives.
5. the pace or duration of the learning process
6. durability of what is retained
7. previous education
8. work experience (and age).

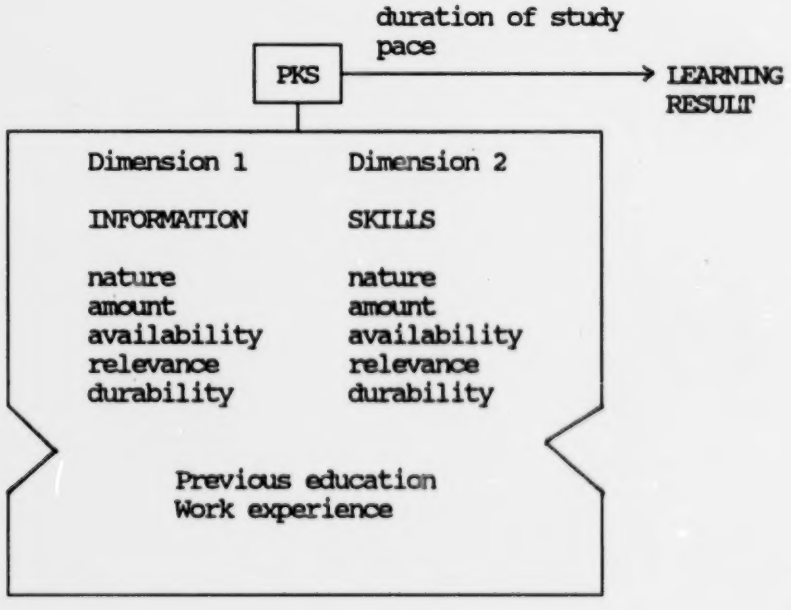


Figure 7. Conceptual model for PKS research

7. Conclusion.

The research described resulted in the proposed conceptual model (figure 7). Operationalizing the variables selected into usable measuring instruments will be described in a following report. Prior to that, the proposed model will be tested in educational practice by means by interviews with students and existing methods for the establishment of variables will be analyzed.

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The 'Prior Knowledge State' of students
and its facilitating effect on learning.

F.J.R.C. Dochy

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